



PEACE/WILLISTON
FISH & WILDLIFE
COMPENSATION
PROGRAM

BChydro 



Survey of Rocky Mountain Elk Along The Peace Arm of Williston Reservoir, North-Eastern BC, February 2000

P. E. Hengeveld and M. D. Wood
April 2001

PWFWCP Report No. 251

The Peace/Williston Fish & Wildlife Compensation Program is a cooperative venture of BC Hydro and the provincial fish and wildlife management agencies, supported by funding from BC Hydro. The Program was established to enhance and protect fish and wildlife resources affected by the construction of the W.A.C. Bennett and Peace Canyon dams on the Peace River, and the subsequent creation of the Williston and Dinosaur Reservoirs.

**Peace/Williston Fish and Wildlife Compensation Program, 1011 Fourth Ave.
3rd Floor, Prince George B.C. V2L 3H9**

Website: www.bchydro.bc.ca/environment/initiatives/pwcp/

**This report has been approved by the Peace/Williston Fish and Wildlife
Compensation Program Fish Technical Committee.**

Citation: P. E. Hengeveld and M. D. Wood. April 2001. Survey of Rocky Mountain elk along the Peace Arm of Williston Reservoir, North-Eastern BC, February 2000. Peace/Williston Fish and Wildlife Compensation Program, Report No. 251. 12pp plus appendices.

Author(s): Pamela E. Hengeveld¹ and Mari D. Wood²

Address(es): ¹ Boreas Ecological Consulting, P.O. Box 1176, Mackenzie, BC V0J 2C0

² Peace/Williston Fish and Wildlife Compensation Program, 1011 Fourth Ave., 3rd Floor
Prince George, B.C. V2L 3H9

Table of Contents

1.0	Introduction	1
2.0	Study Area	2
3.0	Methods	6
3.1	Survey Design	6
3.2	Aerial Survey	7
3.3	Data Analysis	8
4.0	Results and Discussion	9
4.1	Elk Observations	9
4.2	Other Ungulate Observations	10
5.0	Acknowledgements	10
6.0	Literature Cited	11

List of Tables

Table 1.	Climatic characteristics of lower elevation Biogeoclimatic Ecosystem Classification (BEC) units along the Peace Arm of the Williston Reservoir. Data compiled from DeLong et al. 1990, 1994. Values in parentheses are ranges	5
Table 2.	Survey areas and search times for each sample unit surveyed during the Peace Arm Random Stratified Sample Elk Survey, 23-25 February 2000	8
Table 3.	Summary of elk counts and classifications observed during the Peace Arm random stratified sample elk survey, 23-25 February, 2000	9
Table 4.	Summary of estimated elk numbers derived from the Peace Arm random stratified sample elk survey, 23-25 February, 2000	9
Table 5.	Number of moose, deer, and Stone's sheep observed during the Peace Arm random stratified sample elk survey, 23-25 February, 2000	10

List of Figures

- Figure 1. Study area for the stratified random sample elk survey along the Peace Arm of the Williston Reservoir, north-eastern BC, 23-25 February, 2000.....3
- Figure 2. Total High (n=4) and Low (n=15) stratum sample units delineated for the stratified random sample elk survey along the Peace Arm of the Williston Reservoir, 23-25 February, 2000. Four high (H) stratum units, 15 low (L) stratum units 4

List of Appendices

- Appendix A. Survey data for the Peace Arm random stratified sample elk survey, 23-25 February 2000.
- Appendix B. Flight lines and elk group locations for the Peace Arm random stratified sample elk survey, 23-25 February 2000.
- Appendix C. Data analysis (*Aerial Survey* program output file) for the Peace Arm random stratified sample elk survey, 23-25 February 2000.

1.0 Introduction

Elk (*Cervus elaphus*) in British Columbia (BC) experienced dramatic declines in numbers and distribution throughout the late 1800s (Spalding 1992), largely due to excessive harvests, human settlement activities, and severe winters (Demarchi *et al.* 1992, Harper 1988, Peck 1987). Population management (including a number of elk translocations), milder winters, and an increase in early seral forage areas resulting from forest harvesting and fires, have stimulated elk range expansion and population growth throughout the 1900s (Child 1988, Demarchi *et al.* 1992, Ritchie 1992, Spalding 1992). In the early 1990's, the provincial elk population was estimated at 36,325 animals (Demarchi *et al.* 1992). Rocky Mountain elk (*C. e. nelsonii*) are considered plentiful in the Kootenay region of southeastern BC and moderate in the Peace-Liard region of northeast BC, with smaller populations throughout the BC interior (Demarchi *et al.* 1992, Shackleton 1999). In the Peace-Liard region, elk numbers have at least tripled since the 1970s, likely due in part to extensive prescribed burning that has created favourable habitat for elk (Shackleton 1999). Approximately 6,200 Rocky Mountain elk currently reside in northern BC (Child 1988), with an estimated 250 to 300 elk present in the Omineca administrative region (Ritchie 1992). Within the Williston Reservoir watershed, there is a thriving elk population on the north shore of the reservoir's Peace Reach, and small populations in the Ospika, Ingenika, Akie, Pesika, and lower Finlay River drainages (Davidson and Dawson 1990; Spalding 1992; PFWWCP, data on file). Sightings of elk in the Anzac River drainage, Omineca River drainage, and between Mackenzie and Finlay Bay, have also been documented (PFWWCP, data on file).

Elk residing along the north shore of Williston Reservoir's Peace Reach are the result of a translocation of elk from the Kootenay region of BC in the mid 1980's. Between 1985 and 1987, 145 elk were released at Little Dunlevy Lake on the north shore of the Peace Arm to augment the small existing herd of 20-30 elk in the area (Churchill 1987 in Backmeyer 2000; Ritchie 1992; Spalding 1992). More than 5 prescribed burns were conducted between Schooler and Gravel Hill Creeks between 1986 and 1996 to enhance the area's elk winter range (Backmeyer 2000; Corbould 1999; Wood 1996a, 1996b). Five cow elk were radio-collared by the Peace/Williston Fish and Wildlife Compensation Program (PFWWCP) in 1991 and monitored for 3 years to determine seasonal habitat use and movements of transplanted elk, and to assess the potential for future habitat enhancement activities (Backmeyer 2000). Site specific burn plans to further enhance elk winter range in the area were developed in 2000 (PFWWCP, data on file).

To date, no inventories of the size, distribution, or population composition of the elk herd have been conducted. However, Churchill (1987, *in* Backmeyer 2000) suggested that fewer than 20 elk were present in the area during the late 1970s and early 1980s. To evaluate the success of the Peace Arm elk transplant, the PFWWCP conducted a random stratified sample elk survey along the north and south sides of the Peace Arm in February 2000 to determine the herd's current population status. This report presents the results of that survey.

2.0 Study Area

The 'Peace Arm' refers to the eastern extension of the Williston Reservoir in north-central British Columbia (Figure 1). It floods a narrow, steep-sided valley that cuts through the northern Rocky Mountains to the W.A.C. Bennett hydro-electric dam at Hudson's Hope.

The total study area is the Peace Arm drainage. It is 5,833 km² in size, and extends from the height of land of the Rocky Mountains east to the Bennett dam, including tributary drainages on both the north and south sides of the Peace Arm. This area is characterized by high-elevation, mountainous terrain with relatively deep snow in winter. The climate is influenced by the rain shadow effect of the Rocky Mountains, resulting in relatively dry conditions in the east, with increasing precipitation (e.g., greater winter snow depths) toward the Nabesche River in the west. Warm southwest Chinook winds commonly reduce winter snow depths along the eastern Peace Arm.

Suitable winter range for Rocky Mountain elk is limited to lower-elevation portions of the study area, adjacent to the Peace Arm. Moderate (class 3) and high (class 2) quality winter range occurs on open, south aspect slopes along the north shore of the Peace Arm, east of Adams Creek; the remainder of the study area has been described as having nil to low capability of supporting elk (Backmeyer 1994, PFWWCP 1995, Thompson and Lacelle 1992). The survey area therefore included only the portion of the study area where elk were expected to occur in late winter. Specifically, this includes the lower elevation slopes on the north and south sides of the Peace Arm, between the Clearwater drainage in the west, and the Bennett dam to the east (Figure 2).

The topography in this area varies from steep, rocky sidehills west of Schooler Creek to relatively gentle slopes near the Bennett dam (PFWWCP, data on file). Along the north shore of the Peace Arm, west of Schooler Creek, the habitat is predominantly mixed wood forest, with some pockets of open aspen and grassland, and rocky areas.

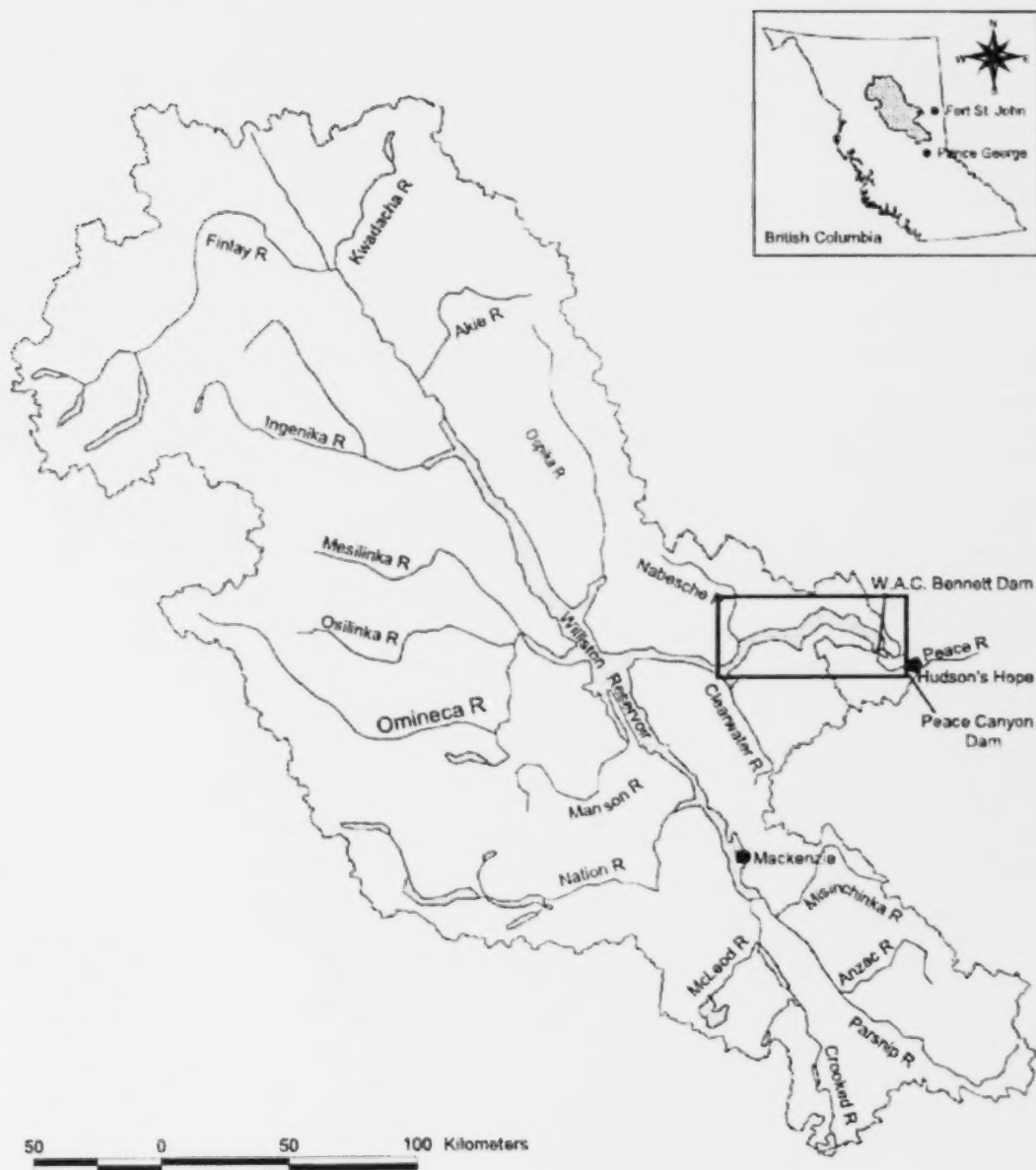


Figure 1. Study area for the stratified random sample elk survey along the Peace Arm of the Williston Reservoir, north-eastern BC, 23-25 February, 2000.

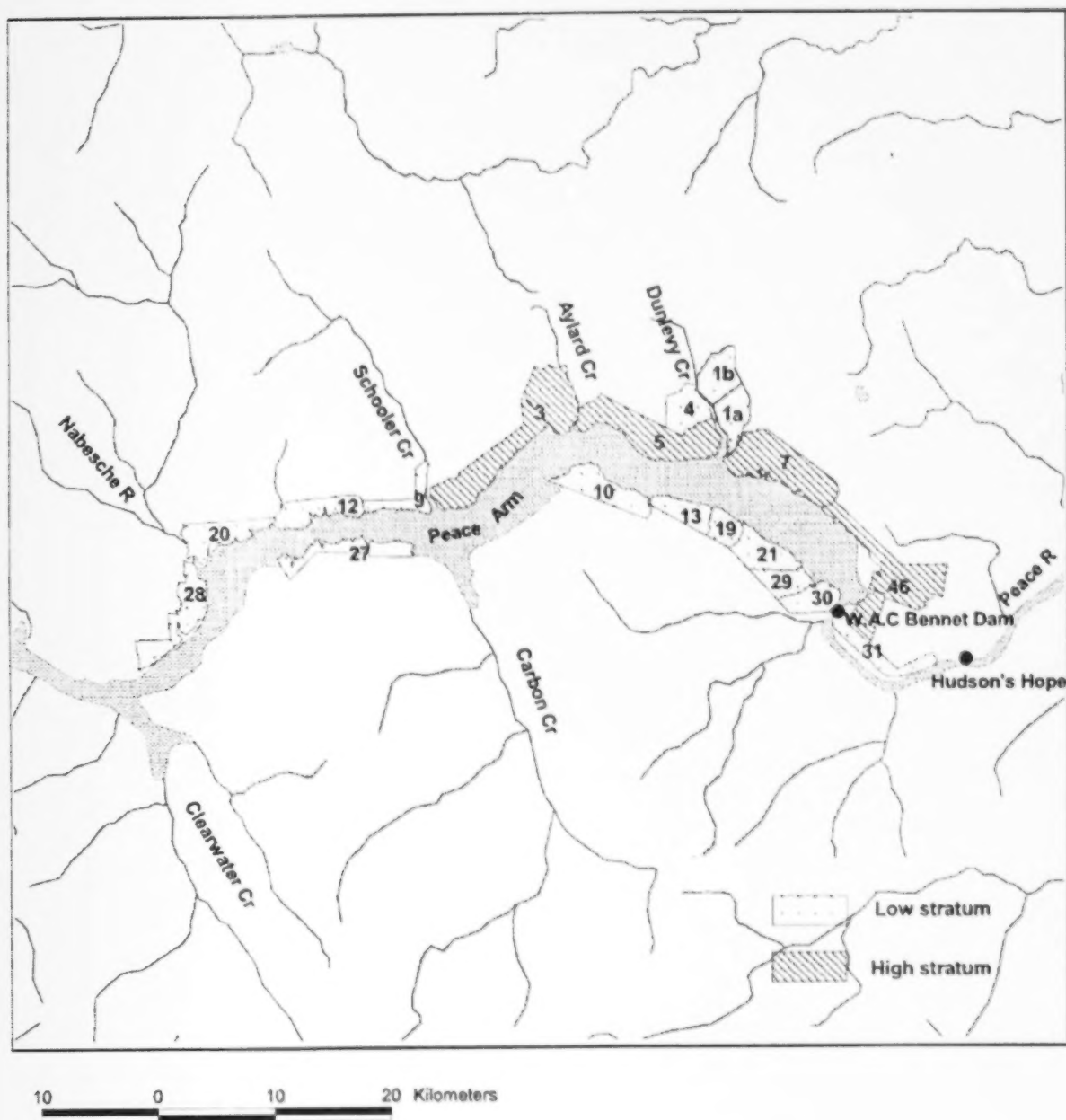


Figure 2. Total High ($n=4$) and Low ($n=15$) strata sample units delineated for the stratified random sample elk survey along the Peace Arm of the Williston Reservoir, 23-25 February, 2000.

The portion of the survey area that hosts high quality elk winter range (i.e., east of Schooler Creek) is characterized by gentle, south aspect slopes, primarily dominated by trembling aspen (*Populus tremuloides*) and open grass-shrub habitats, interspersed with small pockets of conifer forest. Burned areas are visible throughout. Upslope areas are dominated by mature spruce (*Picea spp.*) and lodgepole pine (*Pinus contorta*) forest. West aspect slopes along lower Dunlevy Creek are also aspen dominated, with dense mixed wood and conifer forest in northern and upslope areas. Along the south shore of the Peace Arm, mature conifer forest is dominant, with clearcut patches present.

The survey area is described by variants of three biogeoclimatic zones: Boreal White and Black Spruce (BWBS), Sub-Boreal Spruce (SBS), and Engelmann Spruce - Subalpine Fir (ESSF) (DeLong *et al.* 1990; DeLong *et al.* 1994; MacKinnon *et al.* 1990; BC Environment, data on file; Table 1). Along the north shore of the Peace Arm, the BWBSmwl (moist warm) is found at low elevations (to 1050 m) east of the Nabesche R (DeLong *et al.* 1990; BC Environment, data on file). The BWBSwkl (wet cool) occurs in a narrow band (900-1300 m elevation) above the BWBSmwl, and is replaced at upper elevations (950-1550 m) by moist, very cold variants of the ESSF (i.e., ESSFmv4 between the Nabesche R and Schooler Cr, and ESSFmv2 east of Schooler Cr) (DeLong *et al.* 1990; DeLong *et al.* 1994; BC Environment, data on file).

Table 1. Climatic characteristics of lower elevation Biogeoclimatic Ecosystem Classification (BEC) units along the north and south sides of the Peace Arm of the Williston Reservoir. Data compiled from DeLong *et al.* 1990 (BWBS), DeLong *et al.* 1994 (ESSF), and MacKinnon *et al.* 1990 (SBS). Values in parentheses are ranges.

BEC unit	Mean seasonal precip. ¹ (mm)	Mean annual precip. (mm)	Mean annual snowfall (cm)	Mean annual temperature (°C)
BWBSwkl	320 (230-395)	645 (630-660)	210 (n/a) ²	+0.9 (+0.2 - +1.9)
BWBSmwl	290 (225-355)	485 (395-660)	190 (130-250)	+1.1 (-1.2 - +2.7)
SBSwk2	335 (210-535)	905 (550-1,915)	1,075 (n/a)	+1.0 (-0.1 - +1.7)
ESSFmv2	369 (244-508)	780 (414-1259)	n/a	-0.3 (-1.9 - +1.9)
ESSFmv4	n/a	n/a	n/a	n/a
ESSFwk2	457 (230-684)	1,538 (1,190-1,738)	n/a	+0.3 (-0.5 - +1.0)

¹ Mean seasonal precipitation for the period from May to September.

² n/a indicates data not available.

Along the south shore of the Peace Arm, lower elevations of the survey area are represented by the SBSwk2 (wet cool), with BWBSmwl (moist warm) occurring only east of Table Cr near the Bennett dam (BC Environment, data on file). Upper elevations (950-1300 m) west of the Carbon Cr drainage are characterized by the ESSFwk2 (wet cool), with ESSFmv2 (moist very cold) present to the east (DeLong *et al.* 1994; BC Environment, data on file).

A snow and temperature data logger established by the PFWWCP west of Aylard Creek at 915 m elevation, collected data for the winter/spring periods of 1998/99 and 1999/00. In 1999, snow remained on the ground consistently after 27 November. The maximum snow depths recorded each winter were 0.71 m (28 Feb 99) and 0.57 m (4 Jan 00). The snowpack then declined slowly in each year, reaching 0.45 m on 14 Apr 99 and 0.35 m on 21 Mar 00, before melting rapidly and completely by mid and early April, respectively. Between mid-December and the end of January 1999, average ambient temperature was generally in the -10 °C to -20 °C range, with two short periods of mild temperatures (near 0°C). The coldest temperatures recorded each winter were -21.4°C (23 Jan 99) and -25.4°C (15 Jan 00). Average ambient temperature was consistently above 0°C after 11 Apr 99 and 16 Apr 00.

Overall, open south-aspect slopes on the north shore of the Peace Arm benefit from increased exposure to sunshine and Chinook wind events relative to the densely forested, north-aspect habitats on the south shore. The biogeoclimatic zone variants on the north shore are primarily moist and, at low elevations, warm, while on the south side they are predominantly wet and cool. Given the physical and biogeoclimatic characteristics of each portion of the survey area, snow depths along the south shore can be expected to surpass those on the north shore. Open, wind-blown, south-aspect slopes (i.e. the lower slopes east of Schooler Cr, along the north shore of the Peace Arm) are likely to be favoured by wintering elk.

3.0 METHODS

3.1 Survey Design

We delineated sample units within the greater study area using the reservoir shoreline, creek drainages, and upper elevational contour limits to define unit boundaries. We stratified sample units into 2 strata according to the expected numbers and distribution of elk in the study area: High (>50 elk) or Low (0-50 elk). Unsworth *et al.* (1994) recommend using only these two levels of stratification if no previous survey information exists for an area. Stratification was conducted in the office, and was based on local biologists' knowledge of the elk population and

study area, biogeoclimatic zone maps, elk capability maps, and snow depths. Sample unit sizes recommended by the BC Resource Inventory Committee (RIC) are 10-15 km² for low density units in timbered habitats, and 30-50 km² for high density units in open habitats; they suggest search time per sample unit should take approximately one hour (RIC 1997).

Nineteen sample units were delineated in a 337 km² survey area (Figure 2). Seven of the Low stratum units (n=15) were along the north shore of the reservoir, and 8 were along the south shore. Low stratum units ranged between 10.5 and 16.4 km². All High stratum units (n=4) were located along the north shore of the Peace Arm, and ranged between 31.1 and 43.4 km².

3.2 Aerial Survey

We conducted the survey using a Bell 206 helicopter with a pilot and 3 observers. Sample units were searched in accordance with standard inventory methodology for aerial surveys of elk (RIC 1997, Unsworth *et al.* 1994). Each unit was surveyed completely by flying parallel transects 300-400 m apart, at a height of approximately 50-75 m above ground. We searched for, counted, and classified animals observed in each sample unit. Elk were classified to level 3 RIC standards, identifying calves, cows, yearling males, and bulls (class I, II, III, IV) based on antler presence and characteristics, and body size (RIC 1997). The navigator (Mari Wood, PFWWCP) used a Trimble Pathfinder Differential Pro XR GPS receiver in combination with a TDC2 data collector and Asset Surveyor software (Trimble Navigation Ltd., Sunnyvale, California) to log flight lines and animal locations during the aerial survey. Data files were then transferred from the TDC2 to a PC computer using Pathfinder Office software, exported into GIS, and converted into a coverage for use with the BC Environment *Geographic Object Access Tool* (GOAT) mapping system (BC Environment, Prince George, BC). The rear left seat observer (Pamela Hengeveld, Boreas Ecological Consulting) recorded species, group number and size, animal classifications, and animal activity, and took photographs. The rear right seat observer (Brad Culling, Diversified Environmental Services) recorded habitat type, percent snow cover, and percent vegetation cover for each group location, and described light intensity (i.e., bright or flat) as an indication of animal visibility to the observers.

We conducted the stratified random block survey along the Peace Arm between 23-25 February, 2000. All High stratum units and 5 randomly selected Low stratum units (4 on the north shore and 1 on the south) were surveyed (Table 2). Mean area per sample unit was 14.2 ± 2.3 km² for Low stratum units, and 35.7 ± 5.5 km² for High stratum units.

Table 2. Survey areas and search times for each sample unit surveyed during the Peace Arm random stratified sample elk survey, 23-25 February 2000.

Stratum	Sample Unit	Unit Area (km ²)	Search Time (minutes)
Low	1a	15.8	40
	1b	10.5	50
	10*	16.4	35
	12	13.5	40
	20	14.6	40
High	3	43.4	150
	5	32.6	140
	7	31.1	70
	46	35.6	95
Total	9 units	214 km ²	11.0 hrs

*Low stratum sample unit on south side of Peace Arm

Weather conditions were good during the survey. Precipitation was nil, cloud cover was variable (5-40%), and temperatures were near 0°C on all 3 survey days. Snow cover varied within and among the sample units. Open habitats on lower, south-aspect slopes (i.e., sample units 5, 7, and part of 46) were nearly or completely snow-free. Lower side hills in the Dunlevy Creek drainage (i.e., units 1a and 1b) were 30-50% snow covered; forested and upslope portions of these blocks had 100% snow cover. Western portions of the study area (i.e., units 3, 12, and 20) were mainly 100% snow covered, as were north-aspect slopes (i.e., unit 10).

3.3 Data Analysis

Ungulate aerial survey sightability models developed by Unsworth *et al.* (1994) correct data for visibility bias introduced by independent variables such as group size, snow cover, and vegetation cover. We used the *Aerial Survey* (DOS V4.00r3; Unsworth *et al.* 1994) computer program to derive an elk population estimate for the total survey area (19 sample units), based on actual counts obtained in the sample units surveyed and corrected for sightability biases. We input count data into *Aerial Survey* for analysis, and used the 'Hiller 12E for elk with snow' model to estimate total population size, numbers of each age and sex class, and sex ratios. The model refers to yearling males as 'spikes', Class I and II males as 'raghorns', and Class III and IV males as 'adult bulls'; data were input into the model in this manner.

4.0 Results

4.1 Elk Observations

We observed 448 elk during the survey: 430 in the 4 High stratum units, and 18 in the 5 Low stratum units (Table 3, Appendix A and B). High stratum sample unit 7 had the greatest number of elk (171); this unit included a single group of 162 elk gathered in an agricultural field. Two of the elk observed during the survey still wore radio-collars from the 1991 habitat use study (Backmeyer 2000).

Table 3. Summary of observed elk counts and classifications during the Peace Arm random stratified sample elk survey, 23-25 February 2000.

Stratum	n	Total	Cows	Calves	Spikes	Ragorns	Adult Bulls	Per 100 cows	
								Bulls	Calves
Low	5	18	8	4	0	3	3	75.0	50.0
High	4	430	308	86	28	0	8	11.7	27.9
Total	9	448	316	90	28	3	11	13.3	28.5

The estimated population for the total survey area (19 sample units; 337 km²) is 590 $\pm$ 119 elk (90% confidence interval; Table 4, Appendix C), resulting in a density of between 1.4 and 2.2 elk/km². The density of elk in the entire Peace Arm drainage (5,833 km²) is estimated at 0.08 to 0.12 elk/km². Estimated bull:cow and calf:cow ratios of 21:100 and 30:100 respectively are higher than the observed ratios of 13:100 and 29:100.

Table 4. Summary of estimated elk numbers derived from the Peace Arm random stratified sample elk survey, 23-25 February 2000.

Stratum	n	Total	Cows	Calves	Spikes	Ragorns	Adult Bulls	Per 100 cows	
								Bulls	Calves
Low	15	116	53	22	0	20	20	76.4	42.2
High	4	474	338	94	32	0	10	12.2	27.9
Total	19	590	391	116	32	20	30	20.9	29.8

4.2 Other Ungulate Observations

Fifty-four (54) moose (*Alces alces*), 17 deer (*Odocoileus hemionus* and *O. virginianus*) and 3 Stone's sheep (*Ovis dalli stonei*) were observed incidentally during the survey (Table 5).

Table 5. Number of moose, deer, and Stone's sheep observed during the Peace Arm stratified random sample elk survey, 23-25 February 2000.

Stratum	Sample Unit	Moose	Deer			Sheep
			Mule	White-tailed	Unclassified	
Low	1a	15		3		
	1b	13			2	
	10	5				
	12					
	20	5				
High	3	1				
	5	6				3
	7	13	4			
	46	29	7		4	
Total		87	11	3	6	3

5.0 Acknowledgements

Greg Altoft (Northern Mountain Helicopters) provided exemplary flying skills for this survey. Sample unit delineation and stratification was conducted by Mari Wood (PFWWCP), with input from Brad Culling (Diversified Environmental Services, Fort St. John), Dave King and Glen Watts (BC Environment, Prince George), and Rob Woods (BC Environment, Fort St. John). Sample units were digitized by the GIS department of BC Environment, Prince George.

6.0 Literature Cited

- Backmeyer, R.J. 1994. Peace Arm Williston Lake wildlife capability ratings. Peace/Williston Fish and Wildlife Compensation Program Report No. 33. 52pp.
- Backmeyer, R. 2000. Habitat use and movements of Rocky Mountain elk on the Peace Arm of Williston Reservoir (1991-1994). Peace/Williston Fish and Wildlife Compensation Program Report No. 224. Prince George, BC. 19pp plus appendices.
- Corbould, F.B. 1999. Butler Ridge prescribed burn, 1994. Peace/Williston Fish and Wildlife Compensation Program Report No. 190. 8 pp plus appendices.
- Child, K.N. 1988. Status of some larger mammals in Northern British Columbia and related management issues. Pages 36-50 *in* The Wildlife of Northern British Columbia - Past, Present and Future. Spatsizi Association for Biological Research, Smithers, BC 159pp.
- Davidson, P.W., and R. Dawson. 1990. Williston Wildlife Compensation Program Management Plan 1990. Peace/Williston Fish and Wildlife Compensation Program Report No. 5. Prince George, BC. 44pp.
- DeLong, C., A. MacKinnon, and L. Jang. 1990. A field guide for identification and interpretation of ecosystems of the northeast portion of the Prince George Forest Region. Land Management Handbook Number 22. BC Ministry of Forests, Victoria, BC. 108pp.
- DeLong, C., D. Tanner, and M.J. Jull. 1994. A field guide for site identification and interpretation for the Northern Rockies portion of the Prince George Forest Region. Land Management Handbook No. 29. Ministry of Forests, Victoria, BC. 141pp.
- Demarchi, R.A., A.J. Wolterson, D.W. Janz, K.R. Brunt. 1992. Elk management plan for British Columbia, 1992 - 1997. Wildlife Branch, BC Ministry of Environment, Lands, and Parks, Victoria, BC. 40pp.
- Harper, F. 1988. Regional wildlife plan for the Peace Sub-region, Northern Region. BC Ministry of Environment, Fort St John, BC. 212pp.
- MacKinnon, A., C. DeLong, and D. Meidinger. 1990. A field guide for identification and interpretation of ecosystems of the northwest portion of the Prince George Forest Region. Land Management Handbook No. 21. Ministry of Forests, Victoria, BC. 116pp.

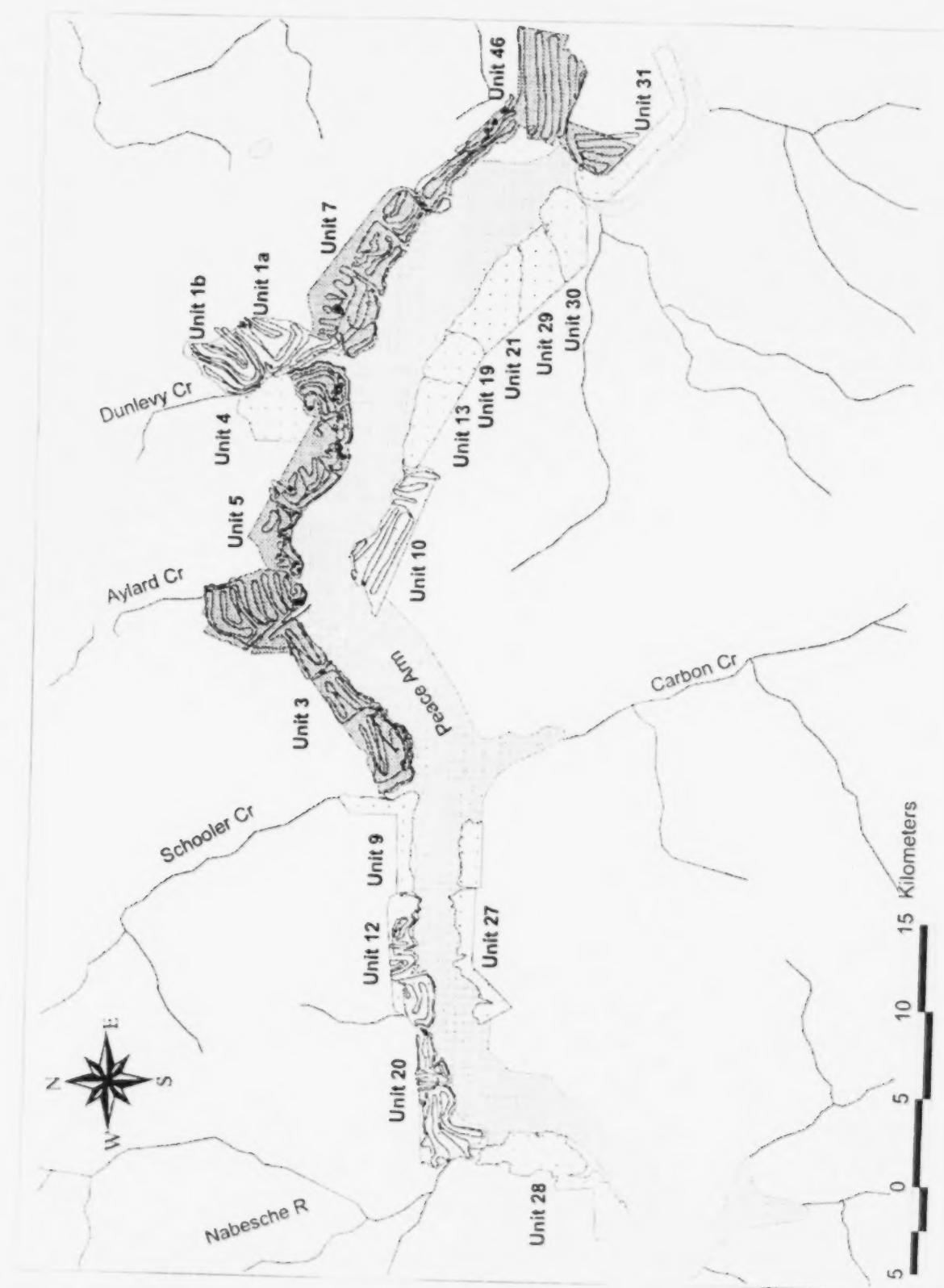
- Peck, R.V. 1987. Responses of elk and vegetation to prescribed fire in the Tuchodi River area of north-eastern BC. MSc Thesis. University of Idaho, Moscow, Idaho. 206pp.
- PWFWCP (Peace/Williston Fish and Wildlife Compensation Program). 1995. Peace Arm / Williston watershed elk capability map. Map scale 1 :50,000. Peace/Williston Fish and Wildlife Compensation Program, Prince George, BC.
- RIC (Resources Inventory Committee). 1997. Standardized inventory methodologies for components of British Columbia's biodiversity: Aerial based inventory techniques for selected ungulates. Version 1.1. Resources Inventory Committee, Ministry of Environment, Lands, and Parks, Victoria, BC.
- Ritchie, D.C. 1992. An Omineca Region perspective on elk. Paper presented at Elk Symposium, Prince George BC, November 14 1992. BC Ministry of Environment, Lands and Parks, Prince George, BC. 8pp.
- Shackleton, D.M. 1999. Hoofed mammals of British Columbia. Royal British Columbia Museum Handbook, Volume 3, The mammals of British Columbia. UBC Press, Vancouver. 268pp.
- Spalding, D.J. 1992. The history of elk (*Cervus elaphus*) in British Columbia. Contrib. Nat. Sci. No. 18. WR 248. Royal British Columbia Museum, Victoria, BC. 27p.
- Thompson, C.E. and L.E.H. Lacelle. 1992. Biophysical habitat classes for the Peace Arm of the Williston Reservoir study area. Peace/Williston Fish and Wildlife Compensation Program Report No. 22. 81pp.
- Unsworth, J.W., F.A. Leban, D.J. Leptich, E.O. Garton, and P. Zager. 1994. Aerial Survey: User's Manual, Second Edition. Idaho Department of Fish and Game, Boise ID. 84pp.
- Wood, M.D. 1996a. Branham Burn, 1993. Peace/Williston Fish and Wildlife Compensation Program Report No. 50. 5pp.
- Wood, M.D. 1996b. Branham Burn, 1995. Peace/Williston Fish and Wildlife Compensation Program Report No. 52. 5 pp.

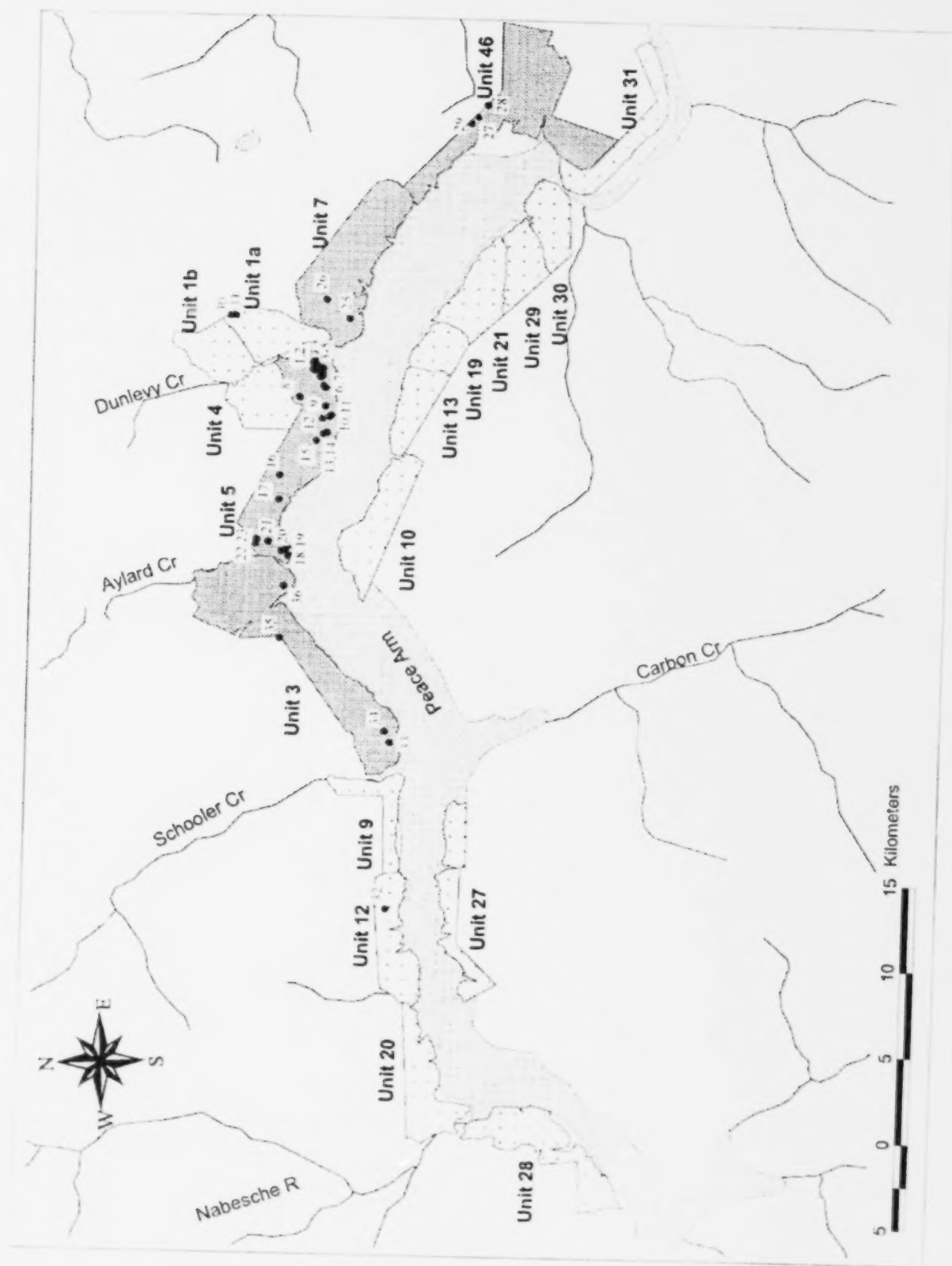
Appendix A. Survey data for the Peace Arm stratified random sample elk survey, 23-25
February 2000.

Appendix A. Survey data for the Peace Arm stratified random sample elk survey, 23-25 February 2000.

Stratum	Unit	Grp#	Group Size	Cows	Calves	Bulls			Snow % Cover	Vegetation % Cover
						Spikes	Ragorns	Adults		
High	5	1	5	3	2				90	30
	5	2	11	9	1	1			95	20
	5	3	11	5	5	1			95	20
	5	4	4	2	2				95	20
	5	5	4	2	2				95	20
	5	6	10	6	4				100	30
	5	7	5	3	1	1			80	30
	5	8	4	3	1				100	80
	5	9	8	4	2	2			100	20
	5	10	1	1					90	20
	5	11	4	3		1			90	60
	5	12	2	2					100	30
	5	13	10	8	2				80	30
	5	14	43	35	6	2			70	5
	5	15	2	2					100	30
	5	16	2	2					100	20
	5	17	1	1					60	5
	5	18	5	3		2			40	2
	5	19	7	5		2			90	15
	5	20	5	4	1				10	0
	5	21	3					3	0	0
	5	22	1					1	100	20
	5	23	2					2		
	7	25	162	133	28	1			100	0
	7	26	9	2	2	5			100	20
	46	27	3	2	1				50	20
	46	28	10	5	4	1			100	20
	46	29	24	12	9	2		1	100	30
	3	33	1					1	100	10
	3	34	16	9	5	2			90	60
	3	35	6	5	1				90	40
	3	36	49	37	7	5			80	20
Subtotal			430	308	86	28	0	8		
Low	1a	30	10	6	4				100	80
	1a	31	2	2					100	60
	1b								0	0
	12	32	6				3	3	90	60
	20								0	0
	10								0	0
Subtotal			18	8	4	0	3	3		
Total			448	316	90	28	3	11		

Appendix B. Flight lines and elk group locations for the Peace Arm stratified random sample
elk survey, 23-25 February 2000.





Appendix C. Data analysis (*Aerial Survey* program output file) for the Peace Arm stratified random sample elk survey, 23-25 February 2000.

Appendix C. Data analysis (*Aerial Survey* program output file) for the Peace Arm stratified random sample elk survey, 23-25 February 2000.

Aerial Survey Model: Elk, Hiller 10-B, Idaho (with snow)

Section 1: Summary of Raw Counts

Units		----- Number of Each Class Counted -----							
Stratum Sampled	Total	Cows	Bulls	BABull	Calves	Spikes	Raghrn	AdBull	Unclass
1	5	18	8	6	4	0	3	3	0
2	4	430	308	36	8	86	28	0	8
	9	448	316	42	14	90	28	3	11

Section 2: Summary of Raw Counts for Perfect Visibility Model

Units			----- Number of Each Class Counted -----							
Stratum Sampled	Total		Cows	Bulls	BABull	Calves	Spikes	Raghrn	AdBull	Unclass
1	5	54	24	18	18	12	0	9	9	0
2	4	430	308	36	8	86	28	0	8	0
	9	484	332	54	26	98	28	9	17	

Units		Percent Correction from Perfect Visibility Model								
Stratum Sampled	Total	Cows	Bulls	BABull	Calves	Spikes	Raghrn	AdBull	Unclass	
1	5	114.9	121.2	125.4	125.4	96.5	0.0	125.4	125.4	0.0
2	4	10.2	9.8	14.8	19.2	9.5	13.6	0.0	19.2	0.0
	9	21.8	17.8	51.7	92.7	19.0	13.6	125.4	75.4	0.0

Section 3: Estimates for Total Number

Total

Number of Units			----- Variance -----				Bound
Stratum	Popn.	Sample	Estimate	Sampling	Sightability	Model	90%
1	15	5	114	3873	877	13	114
2	4	4	474	0	471	4	36
Total	19	9	590	3873	1348	17	119

Cows

Stratum	Number of Units		Estimate	Variance			Bound
	Popn.	Sample		Sampling	Sightability	Model	
1	15	5	53	1878	262	5	76
2	4	4	338	0	238	2	25
Total	19	9	391	1878	500	7	80

Bulls

Stratum	Number of Units		Estimate	Variance			Bound
	Popn.	Sample		Sampling	Sightability	Model	
1	15	5	41	1097	305	0	62
2	4	4	41	0	15	0	7
Total	19	9	82	1097	320	0	62

Branched-antlered bulls

Stratum	Number of Units		Estimate	Variance			Bound
	Popn.	Sample		Sampling	Sightability	Model	
1	15	5	41	1097	305	0	62
2	4	4	10	0	5	0	4
Total	19	9	51	1097	310	0	62

Calves

Stratum	Number of Units		Estimate	Variance			Bound
	Popn.	Sample		Sampling	Sightability	Model	
1	15	5	21	334	77	2	33
2	4	4	94	0	28	0	9
Total	19	9	115	334	105	2	35

Stags

Stratum	Number of Units		Estimate	Variance			Bound
	Popn.	Sample		Sampling	Sightability	Model	
1	15	5	0	0	0	0	0
2	4	4	0	0	10	0	5
Total	19	9	0	0	10	0	5

Raghuorns

Stratum	Number of Units		Variance				Bound 90%
	Popn.	Sample	Estimate	Sampling	Sightability	Model	
1	15	5	20	274	76	0	31
2	4	4	0	0	0	0	0
Total	19	9	20	274	76	0	31

Adult bulls

Stratum	Number of Units		Variance				Bound 90%
	Popn.	Sample	Estimate	Sampling	Sightability	Model	
1	15	5	20	274	76	0	31
2	4	4	10	0	5	0	4
Total	19	9	30	274	81	0	31

Unclassified

Stratum	Number of Units		Variance				Bound 90%
	Popn.	Sample	Estimate	Sampling	Sightability	Model	
1	15	5	0	0	0	0	0
2	4	4	0	0	0	0	0
Total	19	9	0	0	0	0	0

Section 4: Estimates for Proportions

Cows

Stratum	Number of Units		Variance				Bound 90%
	Popn.	Sample	Estimate	Sampling	Sightability	Model	
1	15	5	0.45751	0.04264	0.00740	0.00054	0.36992
2	4	4	0.71386	0.00000	0.00004	0.00002	0.01216
Total	19	9	0.66312	0.00165	0.00031	0.00003	0.07340

Bulls

Stratum	Number of Units		Variance				Bound 90%
	Popn.	Sample	Estimate	Sampling	Sightability	Model	
1	15	5	0.34962	0.08617	0.01478	0.00015	0.52309
2	4	4	0.08726	0.00000	0.00005	0.00000	0.01167
Total	19	9	0.13881	0.00333	0.00060	0.00001	0.10327

Branched-antlered bulls

Stratum	Number of Units		Estimate	Variance			Bound
	Popn.	Sample		Sampling	Sightability	Model	
1	15	5	0.34962	0.08617	0.01478	0.00015	0.52380
2	4	4	0.02013	0.00000	0.00002	0.00000	0.00802
Total	19	9	0.08491	0.08333	0.00059	0.00001	0.10305

Calves

Stratum	Number of Units		Estimate	Variance			Bound
	Popn.	Sample		Sampling	Sightability	Model	
1	15	5	0.19287	0.00756	0.00263	0.00018	0.18761
2	4	4	0.19888	0.00000	0.00004	0.00000	0.01014
Total	19	9	0.19760	0.00029	0.00012	0.00001	0.03395

Spikes

Stratum	Number of Units		Estimate	Variance			Bound
	Popn.	Sample		Sampling	Sightability	Model	
1	15	5	0.00000	0.00000	0.00000	0.00000	0.00000
2	4	4	0.05713	0.00000	0.00003	0.00000	0.00718
Total	19	9	0.05390	0.00000	0.00002	0.00000	0.00737

Ragborns

Stratum	Number of Units		Estimate	Variance			Bound
	Popn.	Sample		Sampling	Sightability	Model	
1	15	5	0.17481	0.02154	0.00369	0.00004	0.26150
2	4	4	0.00000	0.00000	0.00000	0.00000	0.00000
Total	19	9	0.03438	0.00083	0.00014	0.00000	0.05142

Adult bulls

Stratum	Number of Units		Estimate	Variance			Bound
	Popn.	Sample		Sampling	Sightability	Model	
1	15	5	0.17481	0.02154	0.00369	0.00004	0.26150
2	4	4	0.02013	0.00000	0.00002	0.00000	0.00802
Total	19	9	0.05054	0.00083	0.00016	0.00000	0.05183

Unclassified

Stratum	Number of Units		Estimate	Variance		Model	Bound
	Popn.	Sample		Sampling	Sightability		
1	15	5	0.00000	0.00000	0.00000	0.00000	0.00000
2	4	4	0.00000	0.00000	0.00000	0.00000	0.00000
Total	19	9	0.00000	0.00000	0.00000	0.00000	0.00000

Section 5: Estimates for Ratios

Bulls per 100 Cows

Stratum	Number of Units		Estimate	Variance		Model	Bound
	Popn.	Sample		Sampling	Sightability		
1	15	5	76.4	8345.5	542.0	11.2	152.5
2	4	4	12.2	0.0	1.7	0.0	2.1
Total	19	9	20.9	148.5	11.2	0.2	128.8

Calves per 100 Cows

Stratum	Number of Units		Estimate	Variance		Model	Bound
	Popn.	Sample		Sampling	Sightability		
1	15	5	42.2	2053.5	146.7	9.7	11.3
2	4	4	27.9	0.0	4.0	0.0	3.3
Total	19	9	29.8	37.8	5.7	0.2	10.9

Spikes per 100 Cows

Stratum	Number of Units		Estimate	Variance		Model	Bound
	Popn.	Sample		Sampling	Sightability		
1	15	5	0.0	0.0	0.0	0.0	0.0
2	4	4	9.4	0.0	0.6	0.0	1.3
Total	19	9	8.1	0.0	0.5	0.0	1.1

Spikes per 100 Bulls

Stratum	Number of Units		Estimate	Variance		Model	Bound
	Popn.	Sample		Sampling	Sightability		
1	15	5	0.0	0.0	0.0	0.0	0.0
2	4	4	76.5	0.0	21.3	0.9	7.8
Total	19	9	38.8	0.0	5.4	0.2	3.9

Papua New Guinea

Number of Units			Variance				Bound
Stratum	Popn.	Sample	Estimate	Sampling	Sightability	Model	90%
1	15	5	50.0	2400.0	0.0	1.4	88.4
2	4	4	0.0	0.0	0.0	0.1	0.0
Total	19	9	24.7	2400.0	0.0	0.3	43.7

Adult Bull

Number of Units			Variance				Bound
Stratum	Popn.	Sample	Estimate	Sampling	Sightability	Model	90%
1	15	5	50.0	2400.0	0.0	1.4	88.4
2	4	4	23.1	0.0	0.0	0.7	1.4
Total	19	9	36.4	2400.0	0.0	0.5	43.7

Branched or more than one bull per 100 Bulls

Number of Units			Variance				Bound
Stratum	Popn.	Sample	Estimate	Sampling	Sightability	Model	90%
1	15	5	100.0	11500.0	0.0	5.6	176.9
2	4	4	23.1	0.0	21.3	0.7	7.7
Total	19	9	61.1	2807.7	5.4	1.5	87.6

Spikes per 100 Branched antlered Bulls

Number of Units			Variance				Bound
Stratum	Popn.	Sample	Estimate	Sampling	Sightability	Model	90%
1	15	5	0.0	0.0	0.0	0.0	0.0
2	4	4	333.5	0.0	7535.5	139.6	144.1
Total	19	9	62.4	0.0	263.4	4.9	26.9

Section 6: Summary Statistics

[Total variances (i.e., standard error squared) are in parenthesis!]

Total estimates...

590	(	5238)	Total
391	(	2385)	Cows
82	(	1417)	Bulls
51	(	1407)	Branched-antlered bulls
116	(	441)	Calves
32	(	10)	Spikes
20	(	350)	Ragorns
30	(	355)	Adult bulls
0	(	0)	Unclassified

Proportions...

0.6631	(0.001991)	Cows
0.1388	(0.003942)	Bulls
0.0849	(0.003925)	Branched-antlered bulls
0.1976	(0.000426)	Calves
0.0539	(0.000020)	Spikes
0.0344	(0.000977)	Ragorns
0.0505	(0.000993)	Adult bulls
0.0000	(0.000000)	Unclassified

Ratios...

21	(	160)	Bulls per 100 Cows
30	(	44)	Calves per 100 Cows
8	(	0)	Spikes per 100 Cows
39	(	6)	Spikes per 100 Bulls
25	(	707)	Ragorns per 100 Bulls
36	(	707)	Adult bulls per 100 Bulls
61	(	2835)	Branched-antlered bulls per 100 Bulls
62	(	268)	Spikes per 100 Branched-antlered bulls

